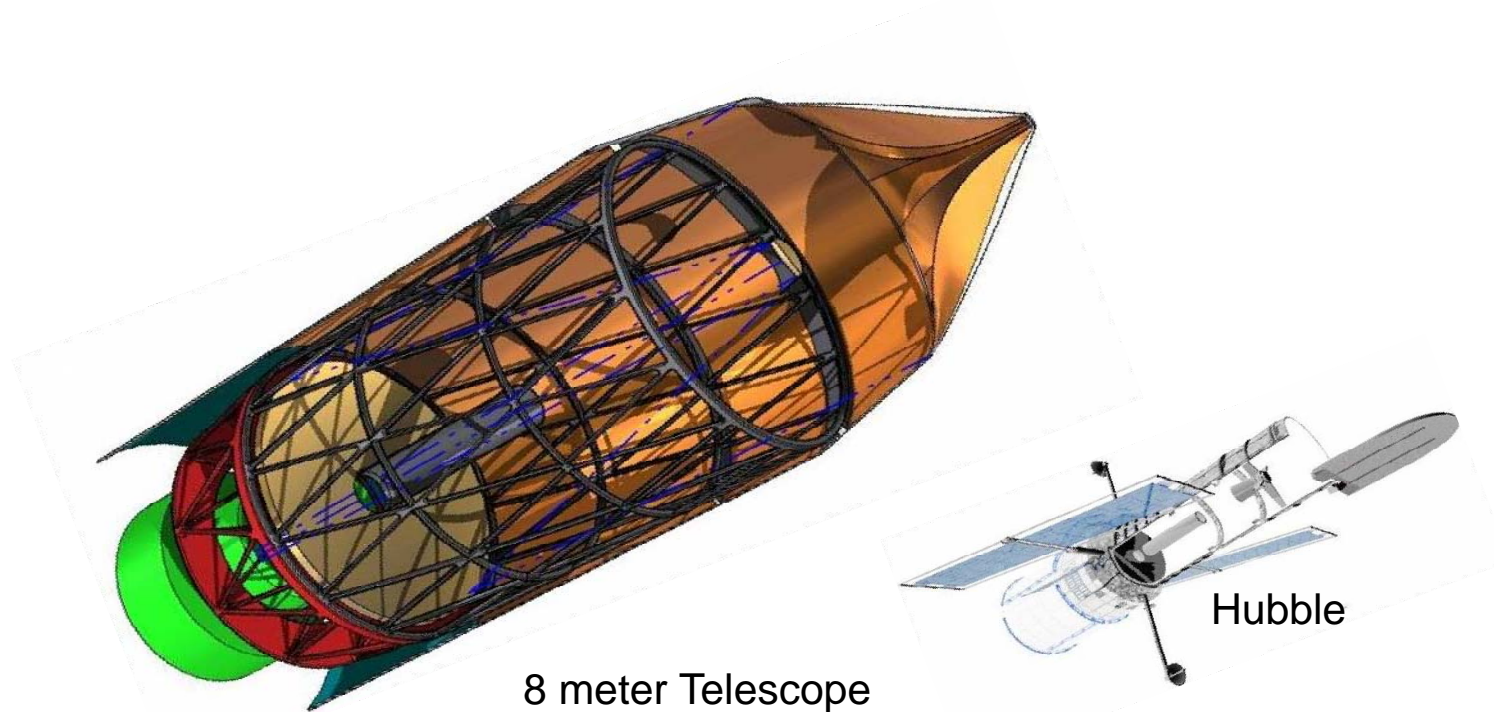




8-meter UV/Optical Space Telescope at L2

H. Philip Stahl, Ph.D.
NASA MSFC





Executive Summary

The unprecedented volume capability of an Ares V enables the launch of 8 meter class monolithic space telescopes to the Earth-Sun L2 point.

The unprecedented mass capability of an Ares V enables an entirely new design paradigm – Simplicity.

Simple high TRL technology offers lower cost and risk.

NASA MSFC has determined that a 6 to 8 meter class telescope using a massive high-TRL ground observatory class monolithic primary mirror is feasible.



Design Concept

8 meter Monolithic Telescope & tube
can fit inside Ares V 10 m envelop.

Minimize **Cost (& Risk)** by using
existing ground telescope mirror
technology – optics & structure.

8-meter diameter is State of Art

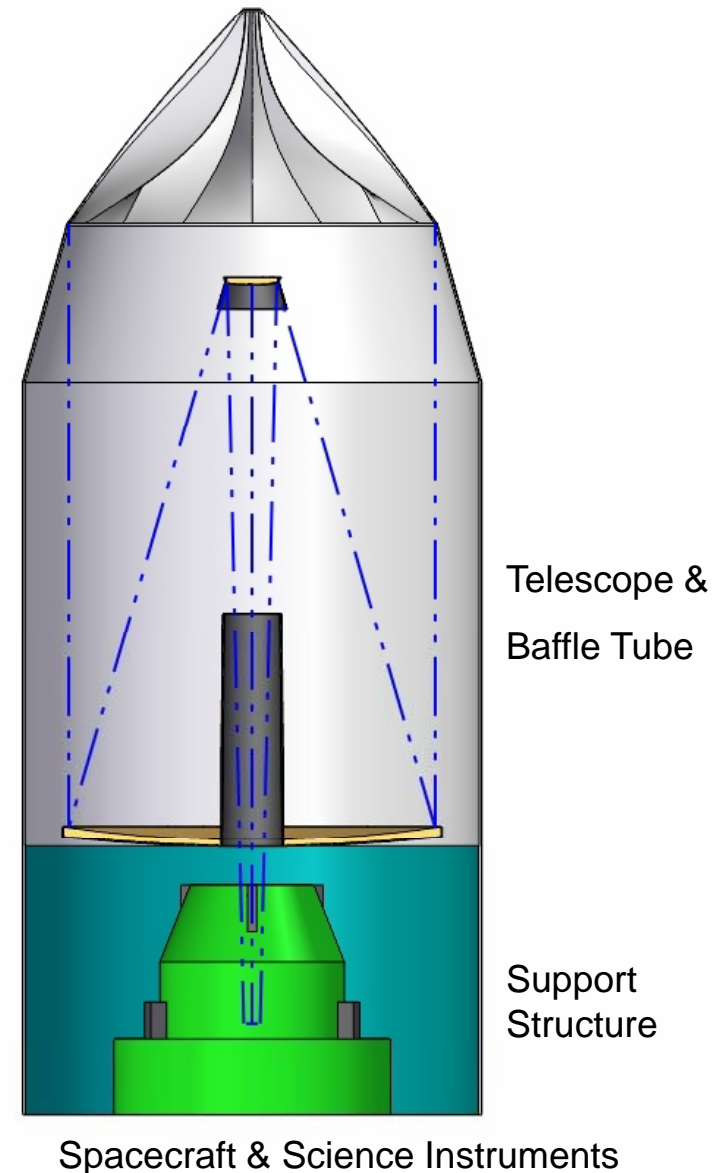
9 existing: VLT, Gemini, Subaru, LBT

23,000 kg (6 m would be ~13,000 kg)

~\$30M (JWST PM cost ~\$120M)

7.8 nm rms surface figure (~TPF spec)

Expect similar savings for structure





6 meter Optical Design

Ritchey-Chretien optical configuration

F/15

Diffraction Limited Performance at <500 nm

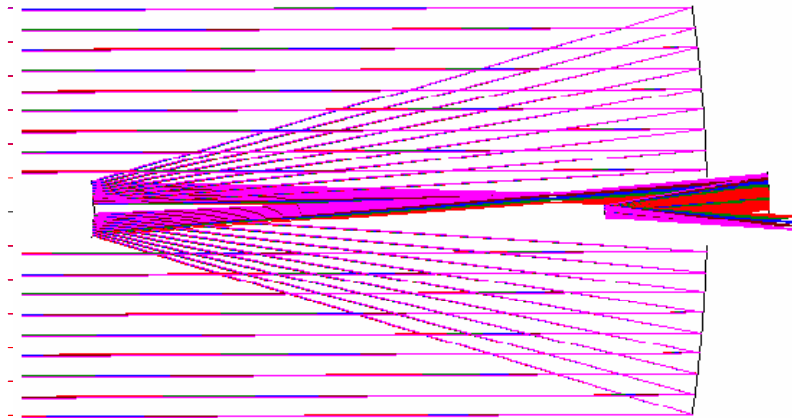
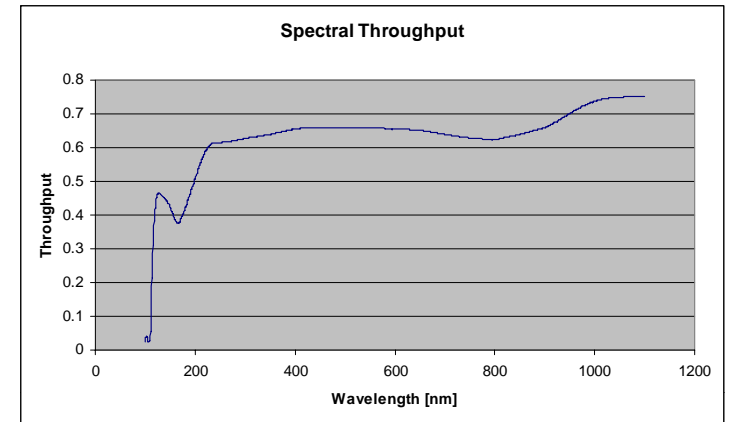
Diffraction Limited FOV of 1.22 arc minute
(10 arc minute FOV with Corrector Group)

Coating: Aluminum with Mg F2 overcoat

Average transmission $> 63\%$ for wave lengths of 200 to 1,000 nm

Primary to secondary mirror vertex: 9089.5 mm

Primary mirror vertex to focal plane: 3,000 mm



All Reflective Design

Three Mirror Anastigmatic

With Fine Steering Mirror

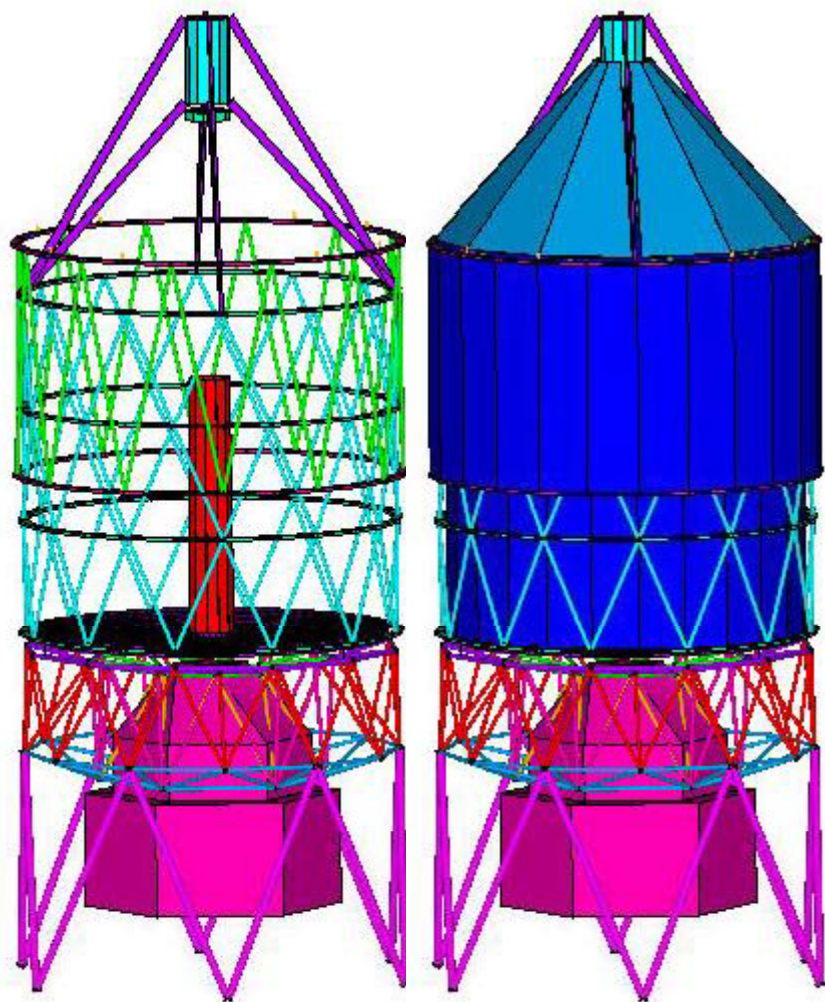
Multi-Spectral 10 arc min FOV

Reduced Throughput



Structural Design

Launch Configuration



Tube is split and slides forward on-orbit.

Faster PM or taller shroud may allow for one piece tube.

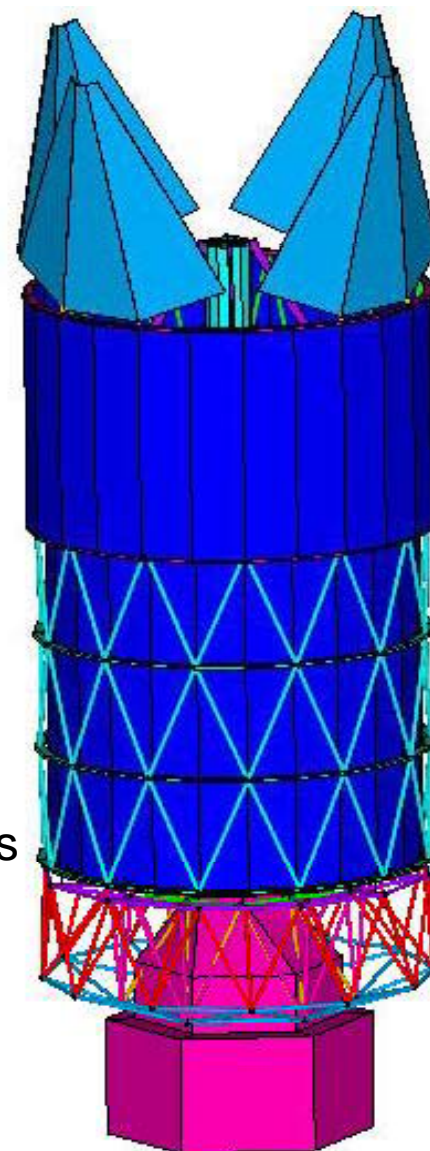
Doors can open/close

Forward Structure is hybrid of Hubble style and four-legged spider

Truss Structure interfaces with 66 mirror support attachment locations

Launch Structure attaches Truss to Ares V

Operational



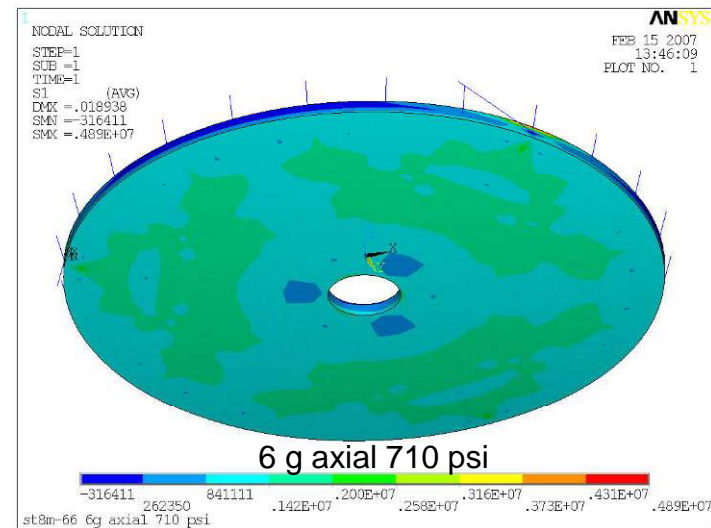
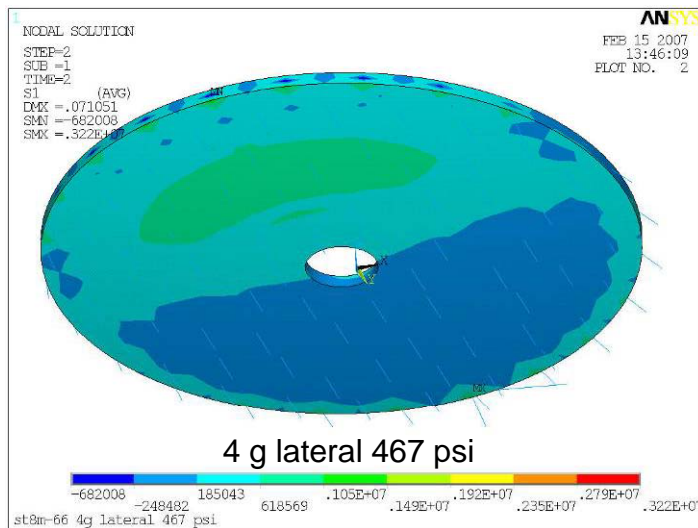


Structural Analysis

Launch loads: *maximum* values from POST3D (not concurrent)

Axial: 4 g's
Lateral-y: 7×10^{-6} g's
Lateral-z: 6×10^{-4} g's

8.2 meter 175 mm thick meniscus primary mirror can survive launch.
66 axial supports keep stress levels below 1000 psi





Spacecraft Structural Modeling

Instrument Frame & Outer Skin Not Shown

3X Docking Latches

Instrument Interface

Upper Shelf

2X GHe Tank Skirt

NTO Tank Skirt

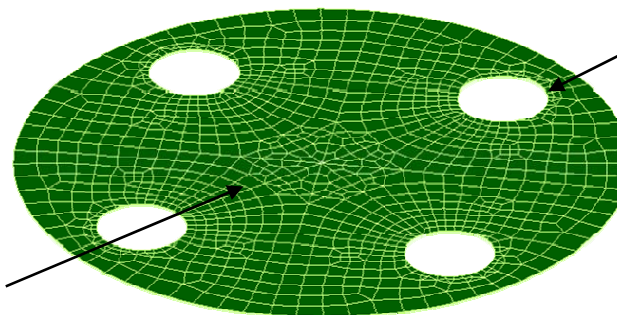
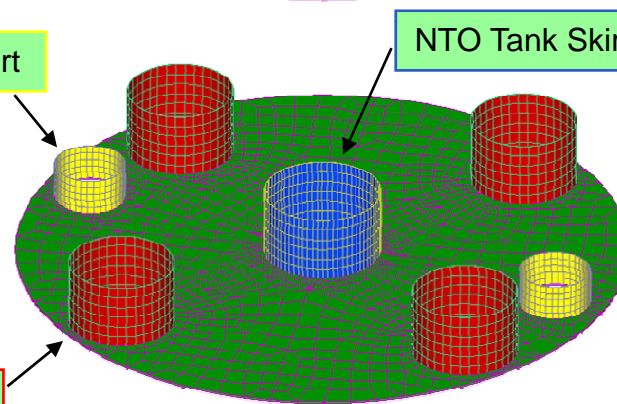
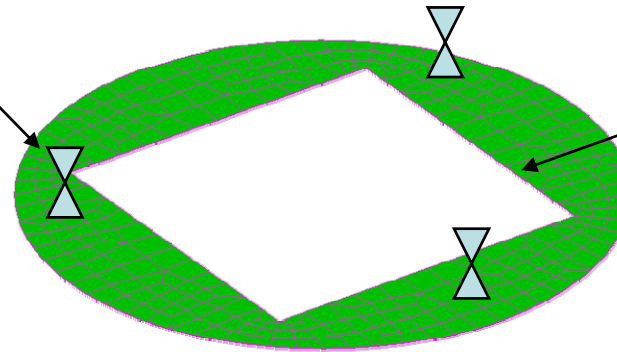
Middle Shelf

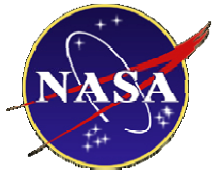
4X MMH Tank Skirt

MPS Nozzle Openings

Lower Shelf

Avionics & Power System Attachments





Spacecraft Structural Analysis Assumptions

Launch Load Case: 4.0g Axial + 2.0g Lateral

Materials: Metallic Structure Only

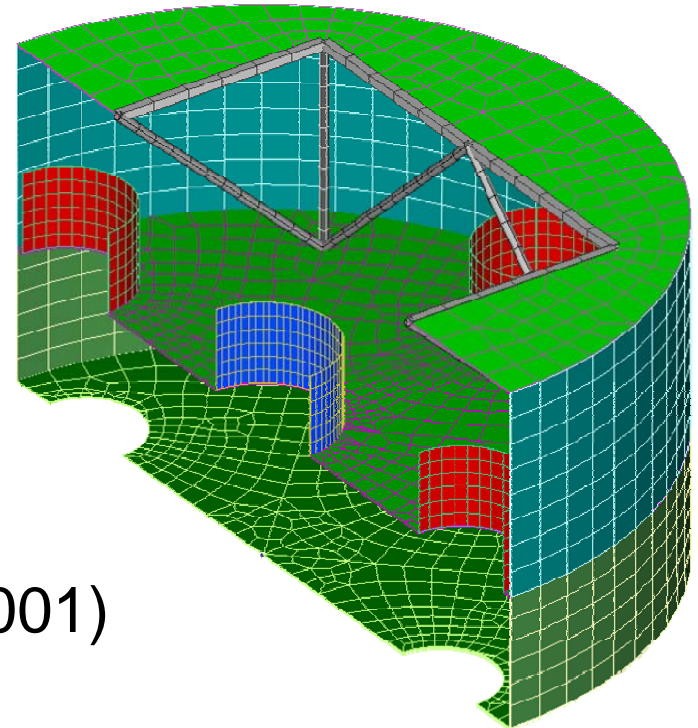
AA 2219 for plate elements

AL 7075 for Beam Elements

Factors of Safety: (per NASA-STD-5001)

Yield Factor of Safety: 1.1

Ultimate Factor of Safety: 1.4



Cross-Sectional View of Spacecraft



Structural Model Results

Upper Shelf:

Shelf: Isogrid Panel 0.090"
(minimum pocket thickness)

Middle Shelf:

Shelf: Isogrid Panel 0.060"
(minimum pocket thickness)

MMH Skirts: 0.064" thk

NTO Skirt: 0.088" thk

GHe Skirt: 0.040" thk

Lower Shelf:

Shelf: Isogrid Panel 0.060"
(minimum (pocket thickness)

Instrument Support Frame:

Upper Support: "T" Beam, 0.095" thk

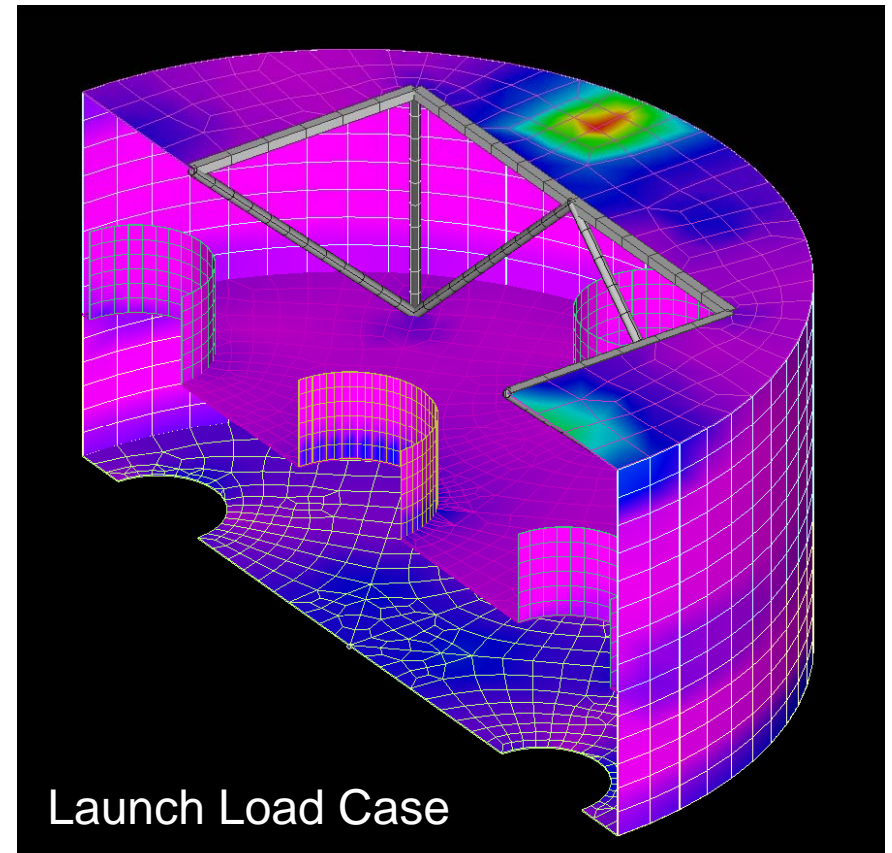
Uprights: 2" diameter, 0.030" thk

Angled Supports: 1.75" diameter, 0.030" thk

Outer Skin:

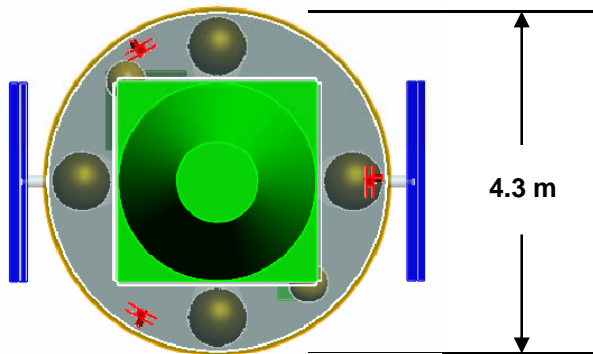
Upper Outer Skin: 0.26" thk

Lower Outer Skin: 0.21" thk

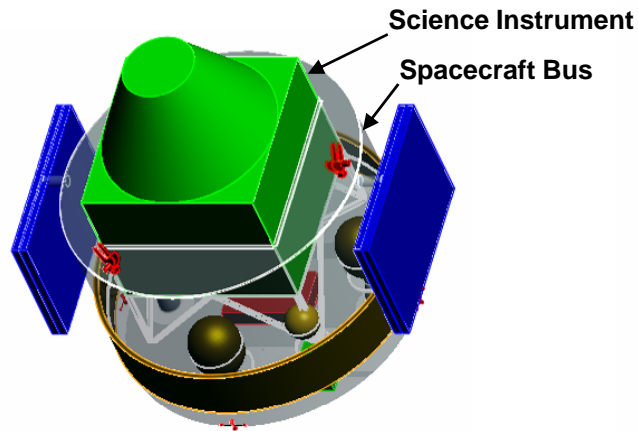




Spacecraft Design Detail & Shroud Integration

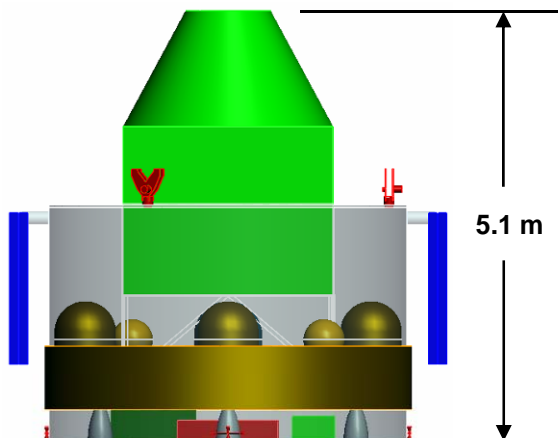


Top View

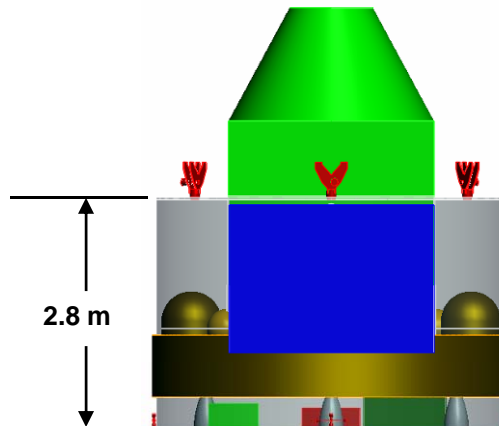


Iso View

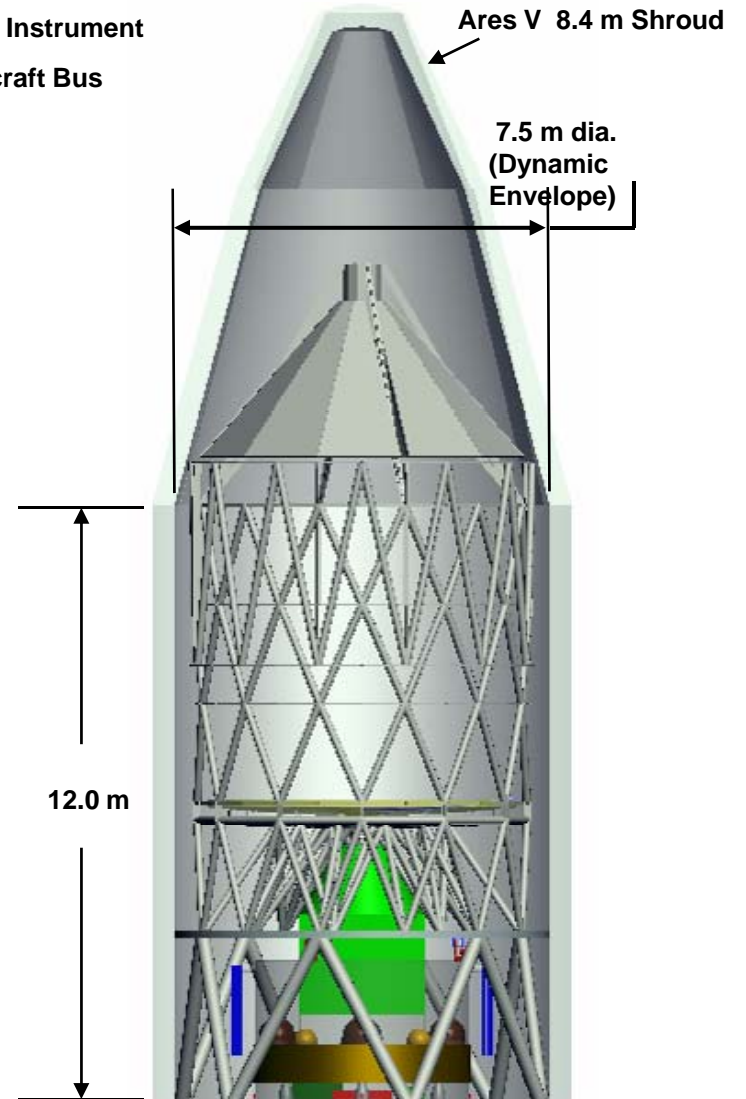
Science Envelope = 2.5 m x 2.5 m x 2.0 m



Front View



Side View



Front View

NOTE: All dimensions are in meters.



6 meter Preliminary Mass Budget

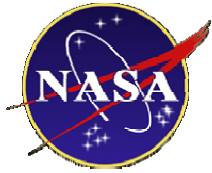
	Mass (Kg)	Heritage	Notes
Primary mirror assembly	20000		
Primary mirror	13,000	calculated	Zerodur 175 mm thk. meniscus
Primary mirror support structure	6,750	estimate	Structual Model
Primary mirror center baffel	250	estimate	Structual Model
Secondary mirror assembly	680		
Secondary mirror	100	calculated	Zerodur 50% light weight
Secondary mirror support & drive	150	estimate	Structual Model
Secondary mirror baffle	30	estimate	Structual Model
Secondary mirror spider	400	estimate	Structual Model
Telescope enclosure	3,600		
Metering structure with internal baffels	2,800	estimate	Marcel Bluth
Rear cover	300	estimate	WAG
Head ring	200	estimate	WAG
Front cover & actuator	300	estimate	WAG
Attitude Determination and Control System	150	JWST	estimate plus JWST scaled
Communications	76	EI63	
Command And Data Handling System	54	JWST	
Power	380	EI63	
Thermal Management System	1090	JWST	400% of JWST
Structures	920	estimate	WAG
Guidance and Navigation	50	estimate	50% WAG
Propulsion	20	JWST	
Computer Systems	50	estimate	WAG
Propellant	50	EI63	
Docking station	1,000	estimate	WAG
OTE W / Bus mass	28,120		
Science Instrument	1500	JWST	ISIM, contains Fine Guidance Sensor
Attitude Determination and Control System	150	JWST	estimate plus JWST scaled
Communications	76	EI63	
Command And Data Handling System	54	JWST	
Power	380	EI63	
Thermal Management System	480	EI63	
Structures	755	estimate	WAG
Guidance and Navigation	50	estimate	50% WAG
Propulsion	250	EI63	
Computer Systems	50	estimate	WAG
Propellant	1530	EI63	
Docking station	1,000	estimate	WAG
Science Instrument W / Bus mass	6,275		

38% Mass Reserve

Total mass = OTE W / Bus + Science Instrument W / Bus =

34,395

8 meter Preliminary Budget is 45,000 kg (~20% Reserve)



Thermal Analysis

Spacecraft wrapped with 10 layer MLI blankets

16.0 m² thermal radiators

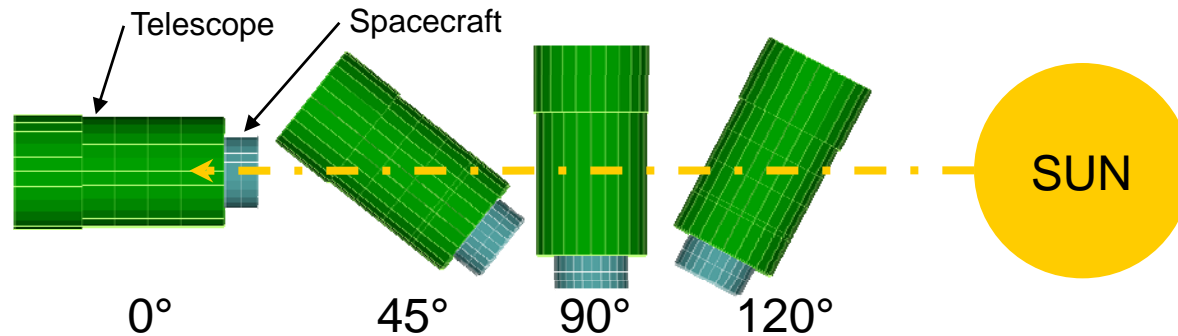
Load Cases

0° (base)

45°

90° (broadside)

120°





Spacecraft Thermal Analysis

Solar Flux at L2 = 1296 W/m^2 applied to base

Instrument Heat Output = 750 W

Avionics Heat Output = 850 W

Propellant tanks modeled as
single nodes with heat leaks
from the spacecraft walls

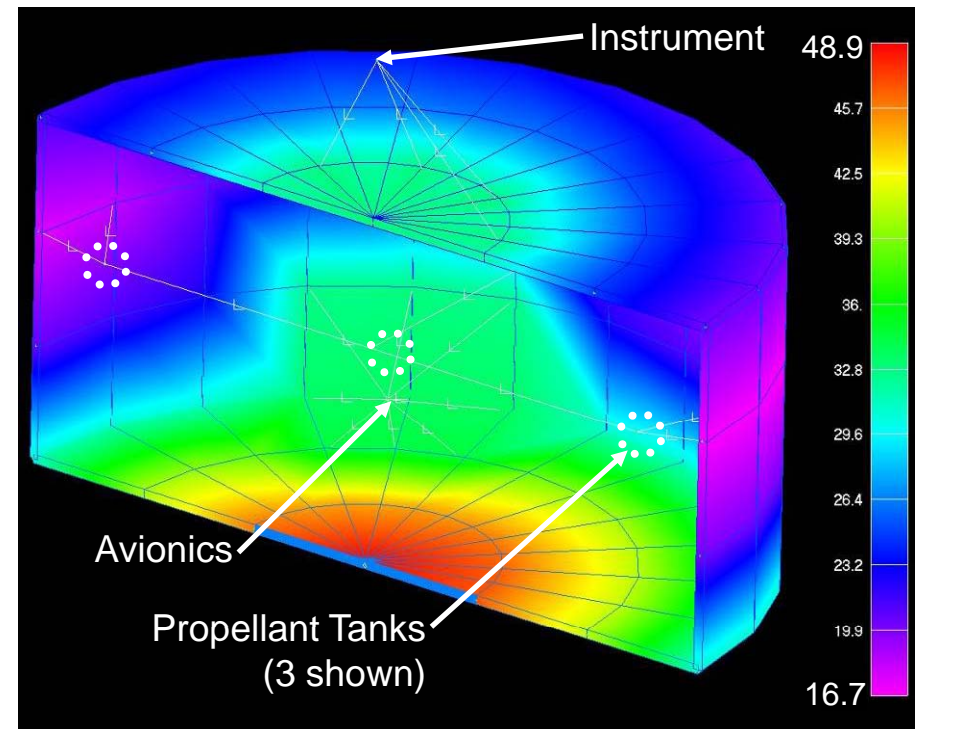
Steady-state operational
temperatures determined

Spacecraft wrapped with
50 layer MLI blankets

16.0 m^2 thermal radiators

Propellant tanks maintained with MLI and heaters

Heaters required to keep propellant from freezing

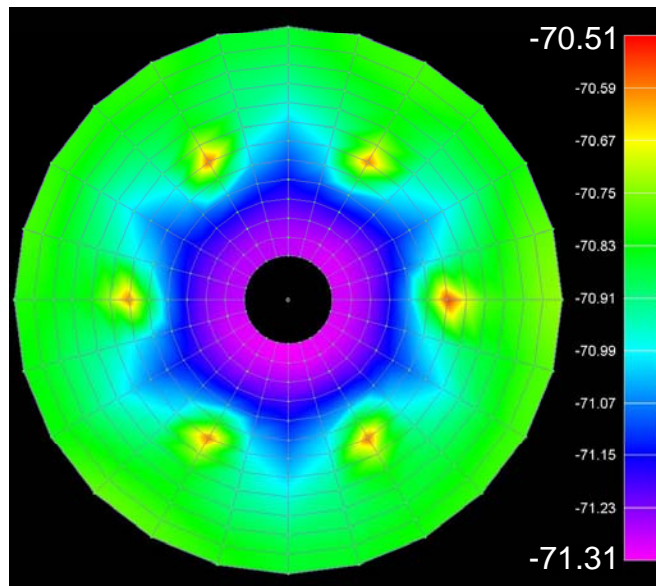


Temp in °C

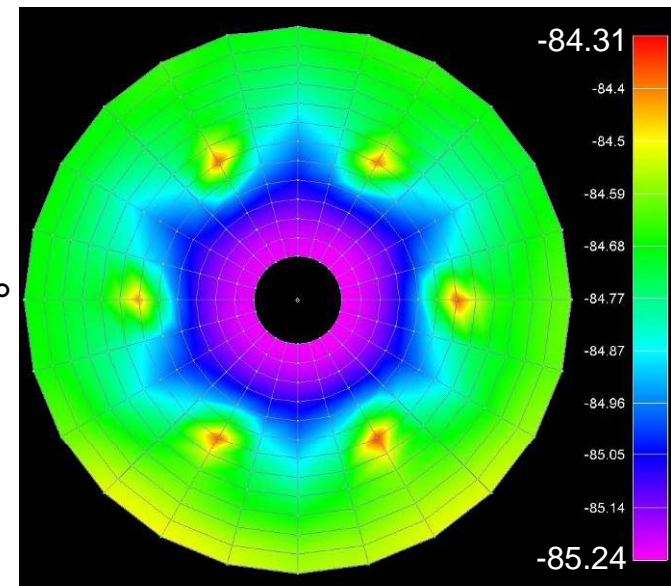


Primary Mirror Thermal Analysis Results

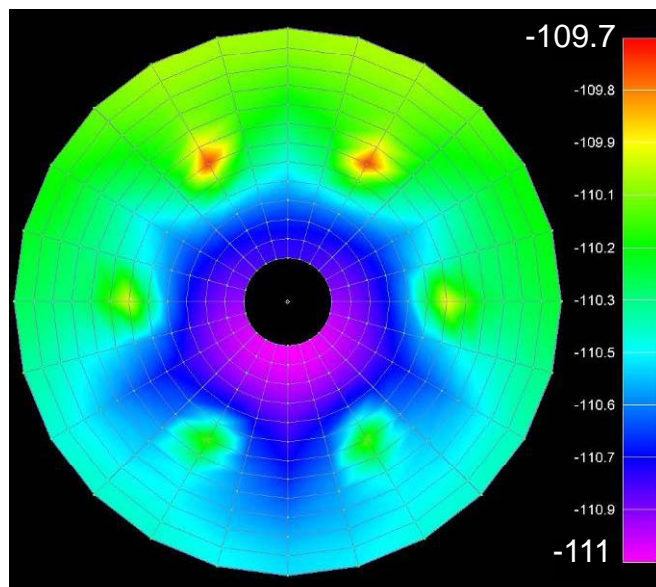
Sun = 0°



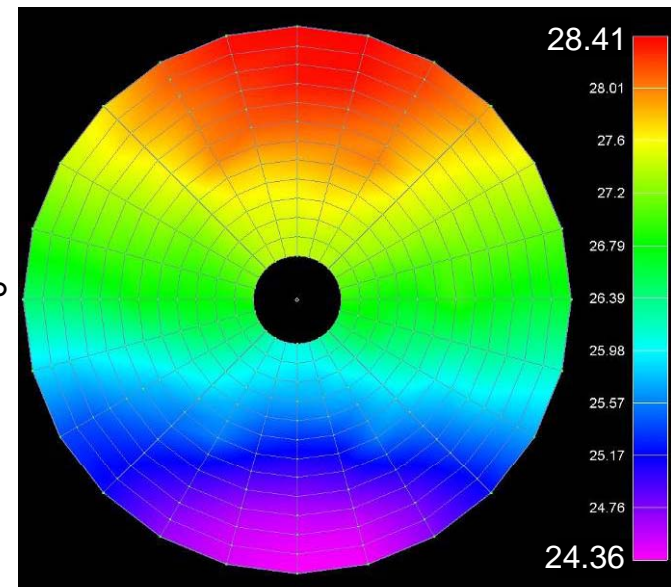
45°



90°



120°



* Temperatures are in °C. Note varied temperature scale for each load case.



Primary Mirror Thermal Analysis

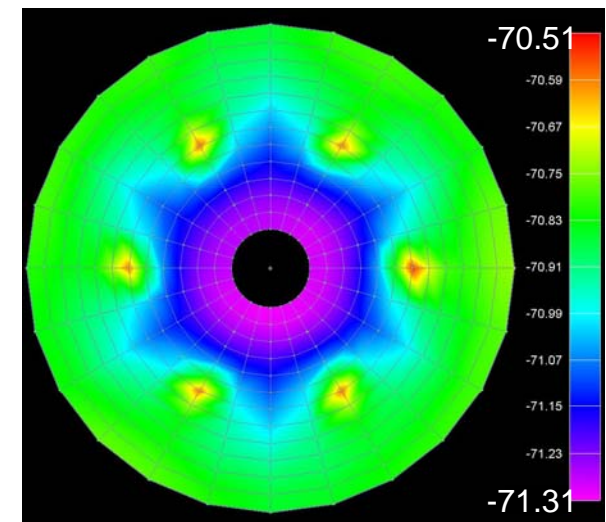
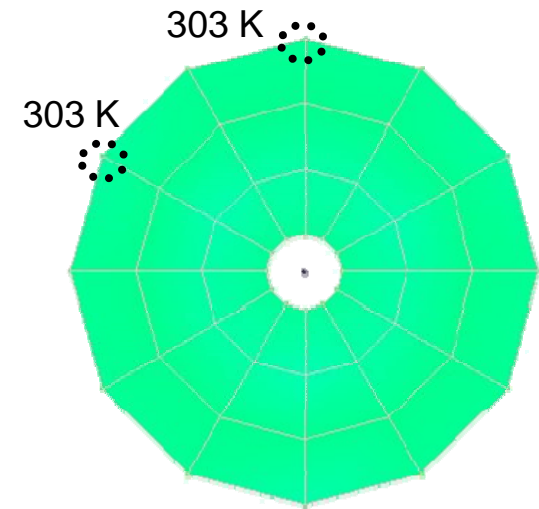
Active Thermal Management via 14 Heat Pipes yields a Primary Mirror with less than 1K Thermal Variation.

No Thermal Management yields a Cold PM

Sun Angle	Temp
0 deg	200K
90 deg	160K
120 deg	300K
with 1K Thermal Variation	

Thus, possible End of Life use as a NIR/Mid-IR Observatory.

Figure Change will be driven by CTE
Change from 300K to 150K
Zerodur CTE is approximately 0.2 ppm.
SiO₂ CTE is approx 0.6 ppm.

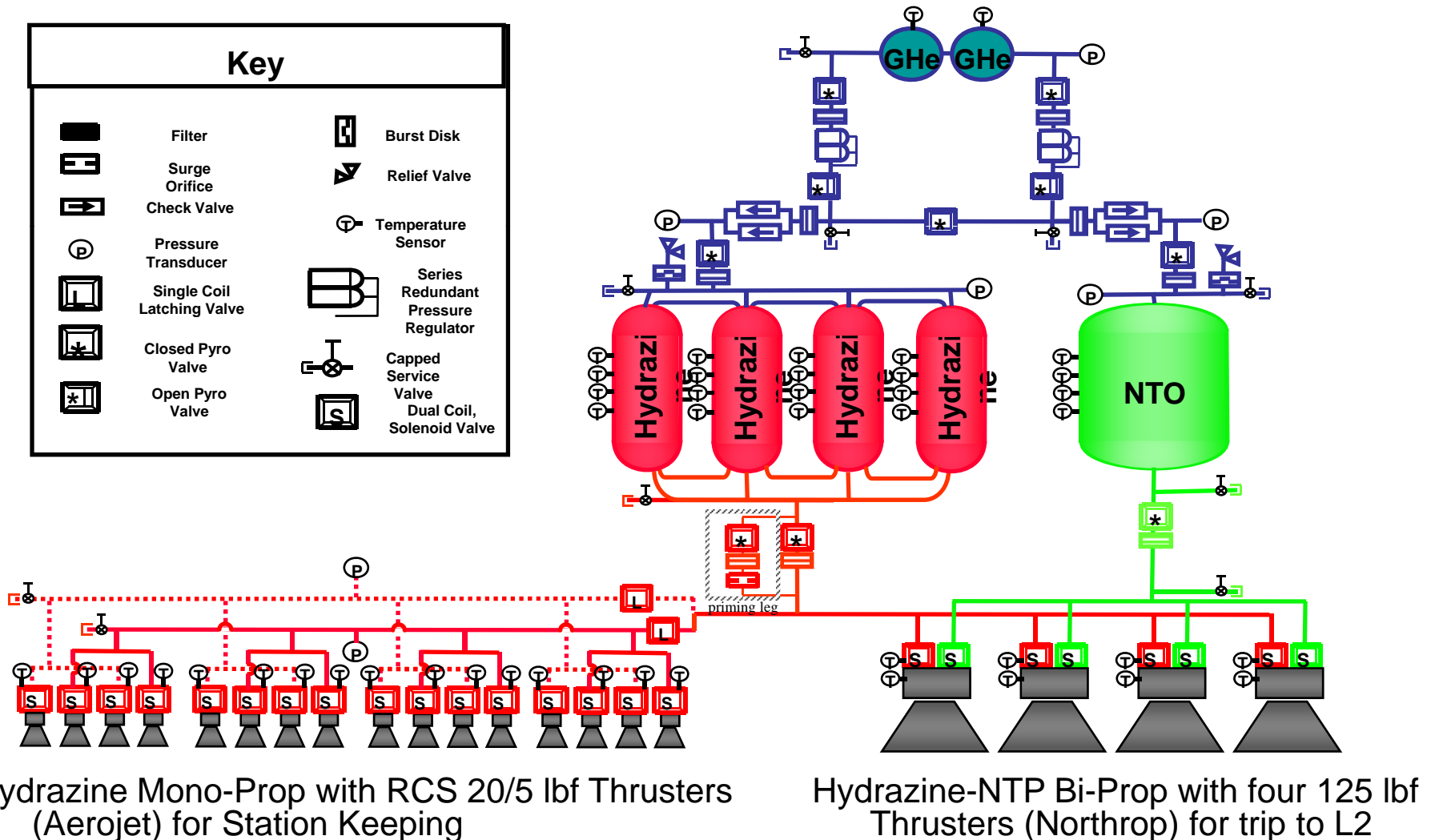




Notional Spacecraft Propulsion System

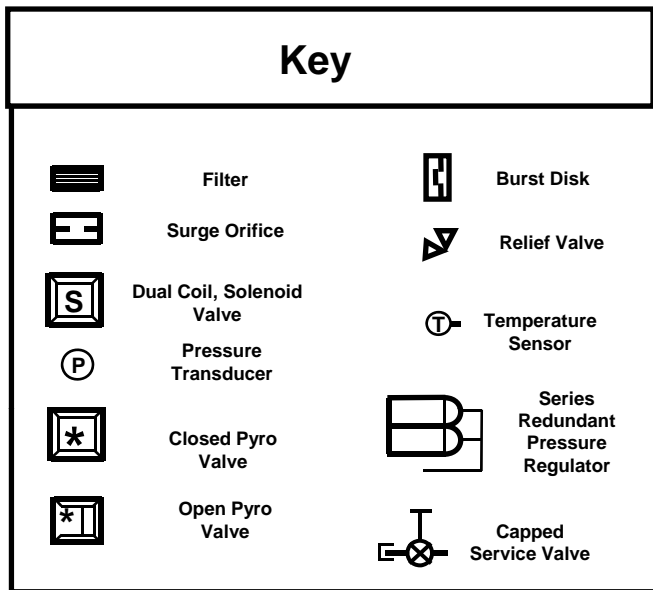
Dual Mode: Hydrazine-NTP Bi-Prop / Hydrazine Mono-Prop

Propellant for 5 yr mission with redundant Thrusters





Notional Telescope Propulsion System

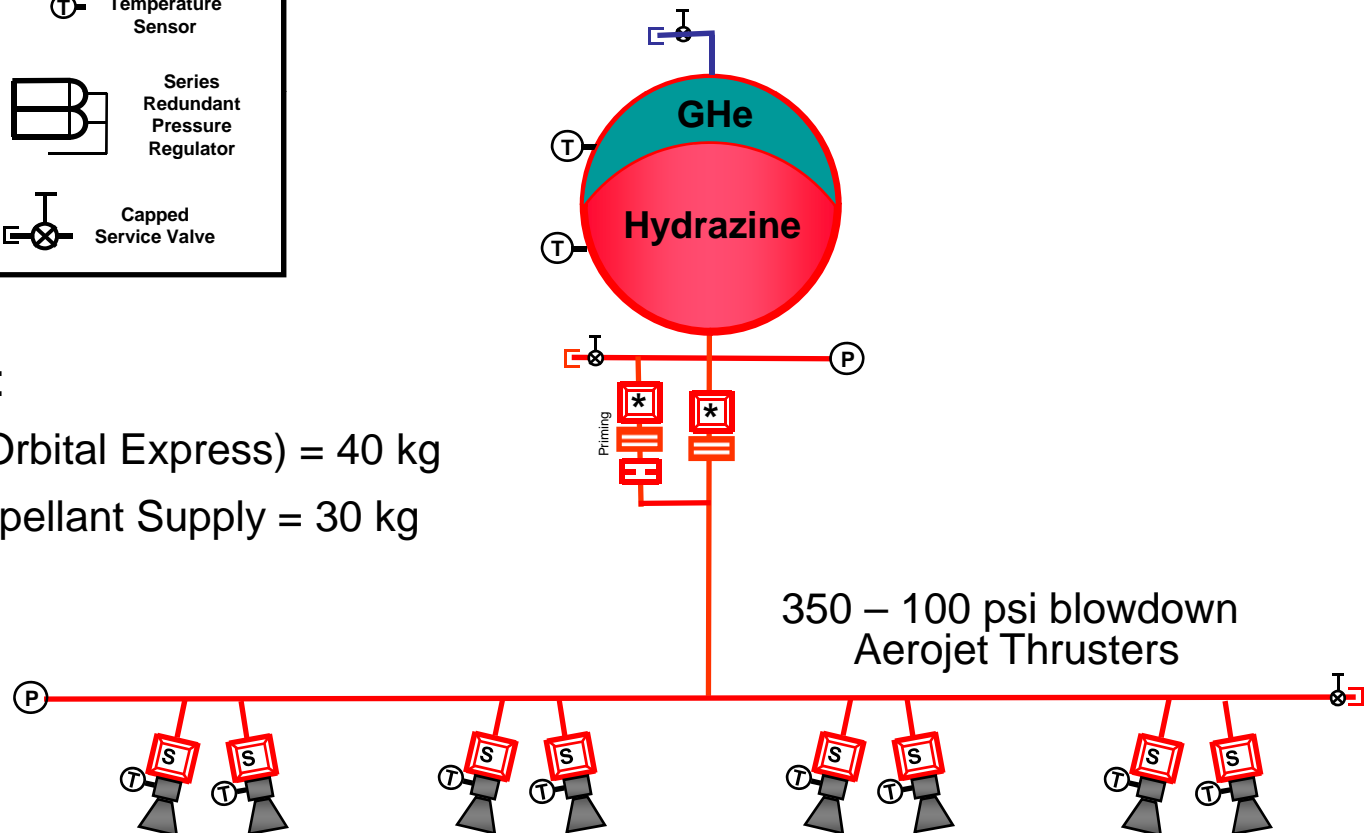


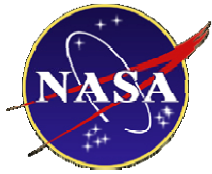
Telescope has Independent Control System
Mono-Propellant Hydrazine

Trade Analysis:

Refueling (Orbital Express) = 40 kg

30 Year Propellant Supply = 30 kg



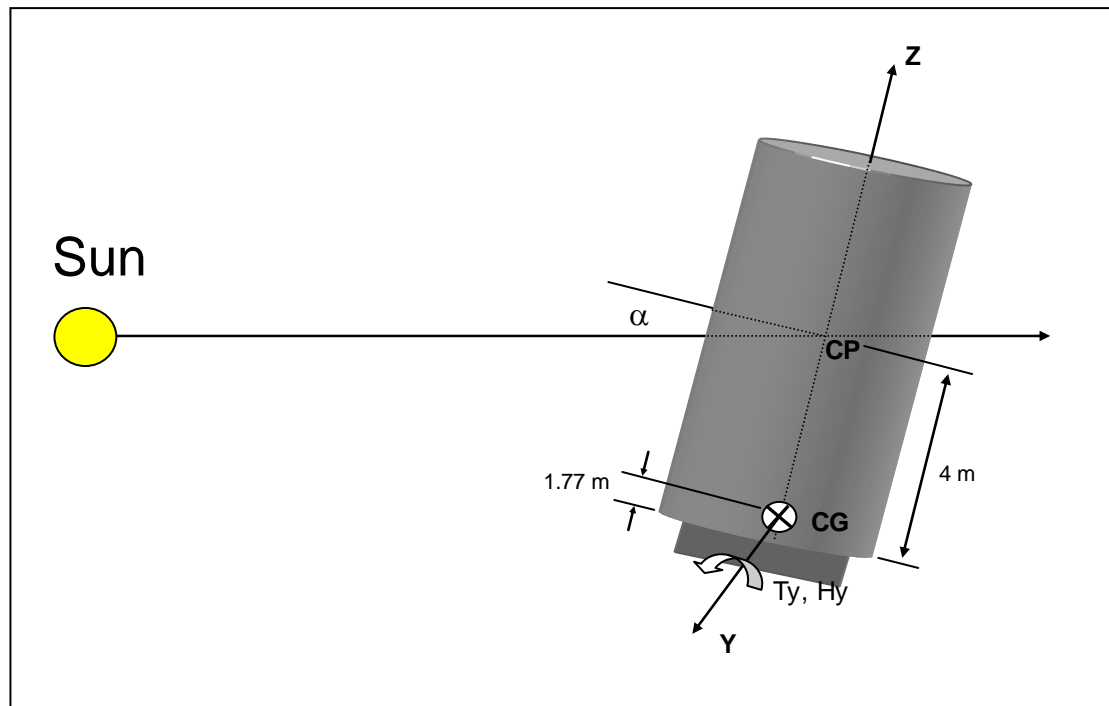


Guidance Navigation and Pointing Control

Spacecraft Reaction Wheels provide all GNC

Worst condition for solar radiation pressure torque is at sun angle = 90.

Momentum buildup occurs in one axis (y-axis)





GN&C Analysis

Two performance Parameters were analyzed and plotted against each other:

- Hours that Telescope can stare at a fixed point (remain at an inertial hold) before needing to perform a momentum dump due to solar radiation pressure torque
- How fast in minutes the Telescope can perform a 60 degree slew

6 wheel and 4 wheel configurations were analyzed along with the worst case single wheel failure for each configuration.

Each configuration was analysis for three different TELDIX reaction wheel versions with different (Torque : Momentum Storage)

Analysis

is only for the worst case sun angle = 0

As the sun angle increases so does the available science time.

did not account for any solar panel contribution to solar pressure cp location.

This is worst case since accounting for the solar panels would move the cp location closer to the cg. Also, Telescope geometry is preliminary and may change due refinement in design

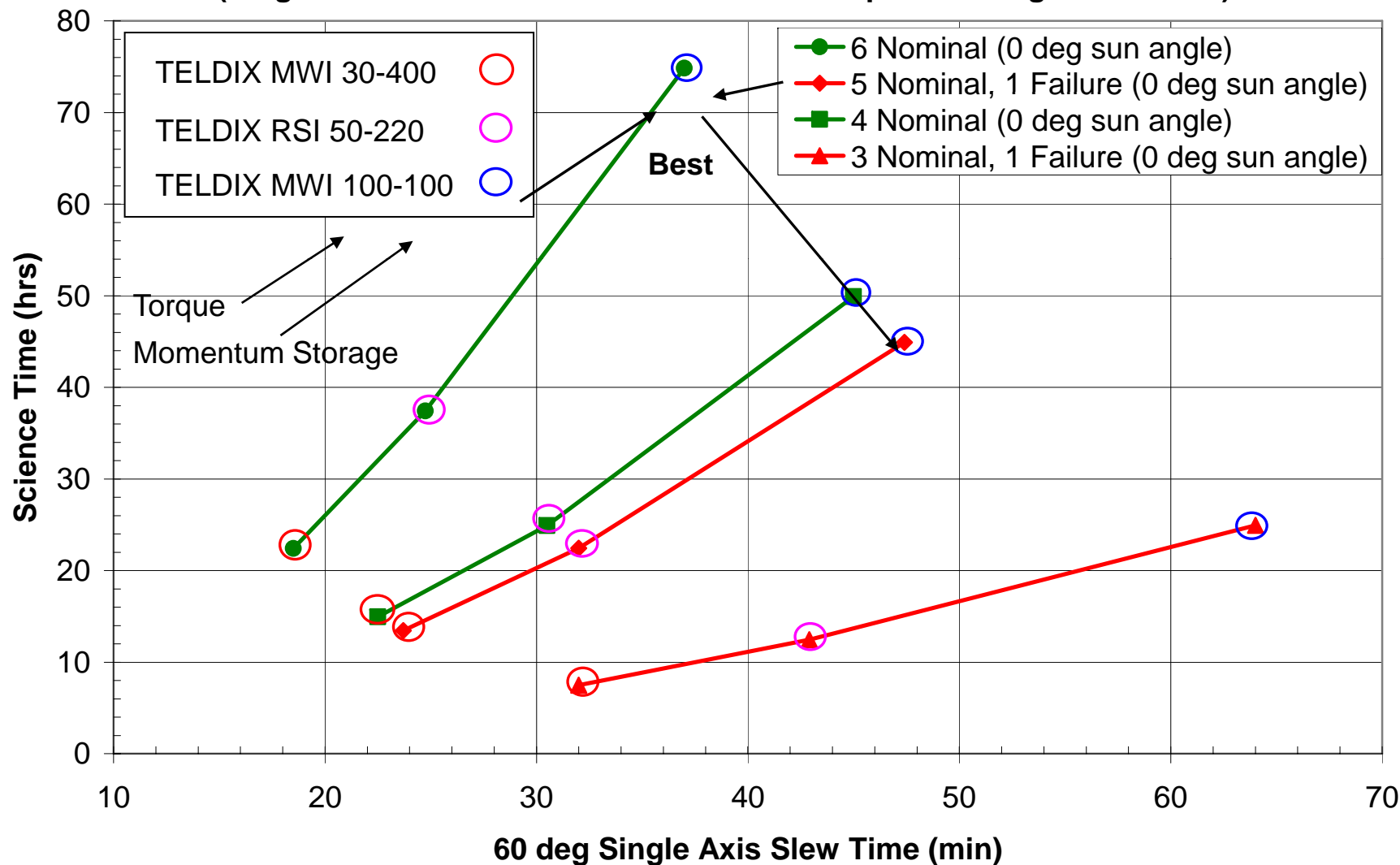


GNC: Reaction Wheels

Science Time vs Slew Time

6 and 4 Reaction Wheel Configurations

(Single Axis Solar Pressure Disturbance Torque and Single Axis Slew)





Avionics and Power Systems Assumptions

Spacecraft

Avionics

- Spacecraft avionics systems are 1-fault tolerant for 5 year life
- Guidance and navigation system includes star trackers, sun sensors, and IMUs
- AR&D consists of a LIDAR long range system, and an optical short range system
- Computers handle all normal station keeping, maneuvers, data management, and ground communications
- Communication systems consist of Ka-band HGA for ground, and s-band for local comm and backup capability

Power

- Spacecraft power systems are 1-fault tolerant for 5 year life
- Power generation from two 9 m² deployable solar array wings with pointing ability
- Batteries are sized for 2 hours of power for midcourse and rendezvous operations (with arrays retracted)
- Spacecraft power system includes 800 w for mirror thermal control, and 750 w for telescope instrument package



Avionics and Power Systems Assumptions

Telescope

Avionics

- Telescope avionics systems are 3-fault tolerant for 30 year life
- Minimal guidance and navigation system, used only for station keeping during spacecraft exchange
- Minimal computer capability, used mainly for station keeping during spacecraft exchange
- All health and status data sent directly to spacecraft avionics system
- Low gain communications capability with the servicing spacecraft only

Power

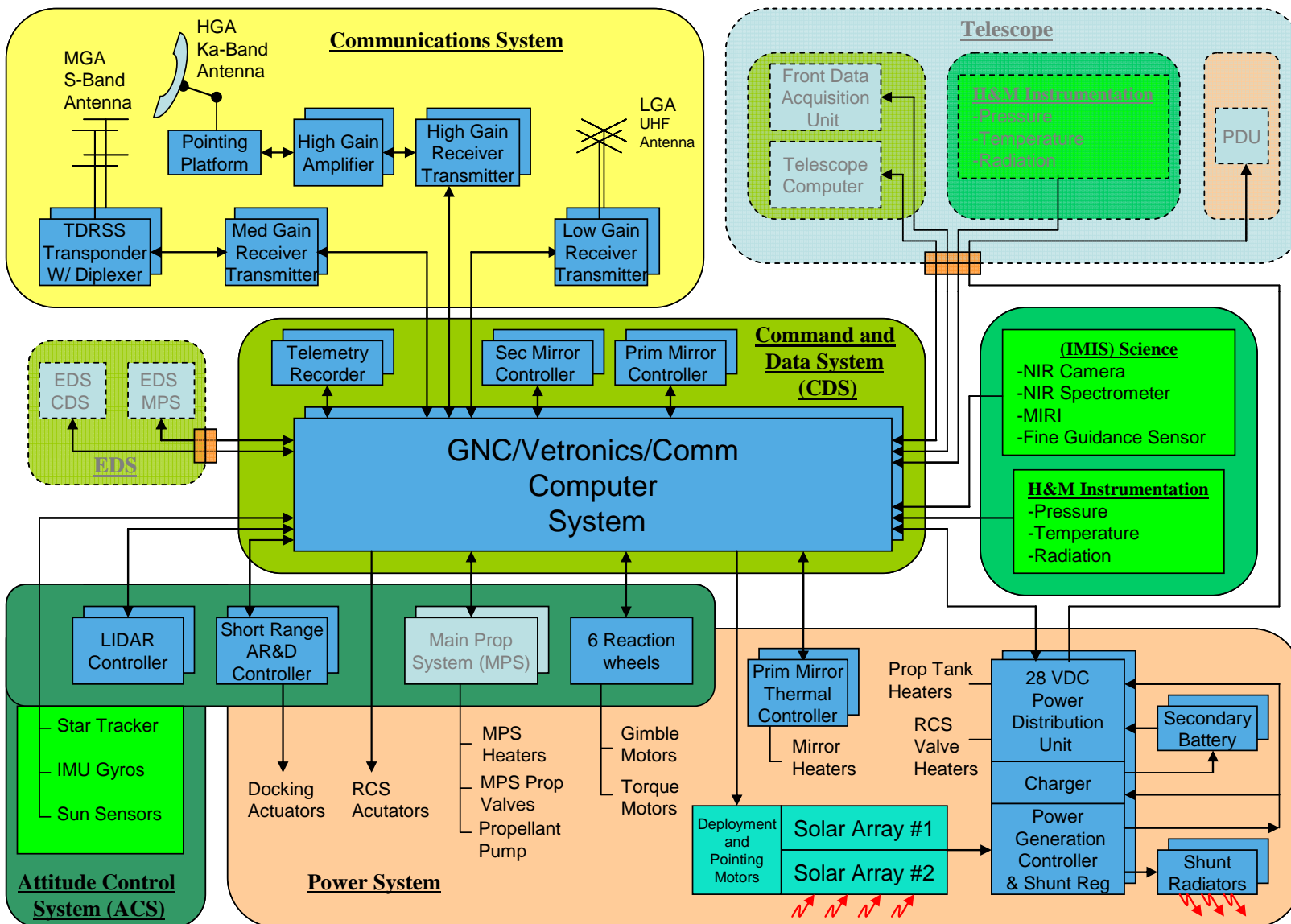
- Telescope power systems are 3-fault tolerant for 30 year life
- 18 m² body mounted solar array around light tube, used for station keeping during spacecraft exchange
- Batteries sized for 0.5 hour attitude control contingency
- No active mirror thermal control during spacecraft exchange



Spacecraft Astrionics & Power Systems

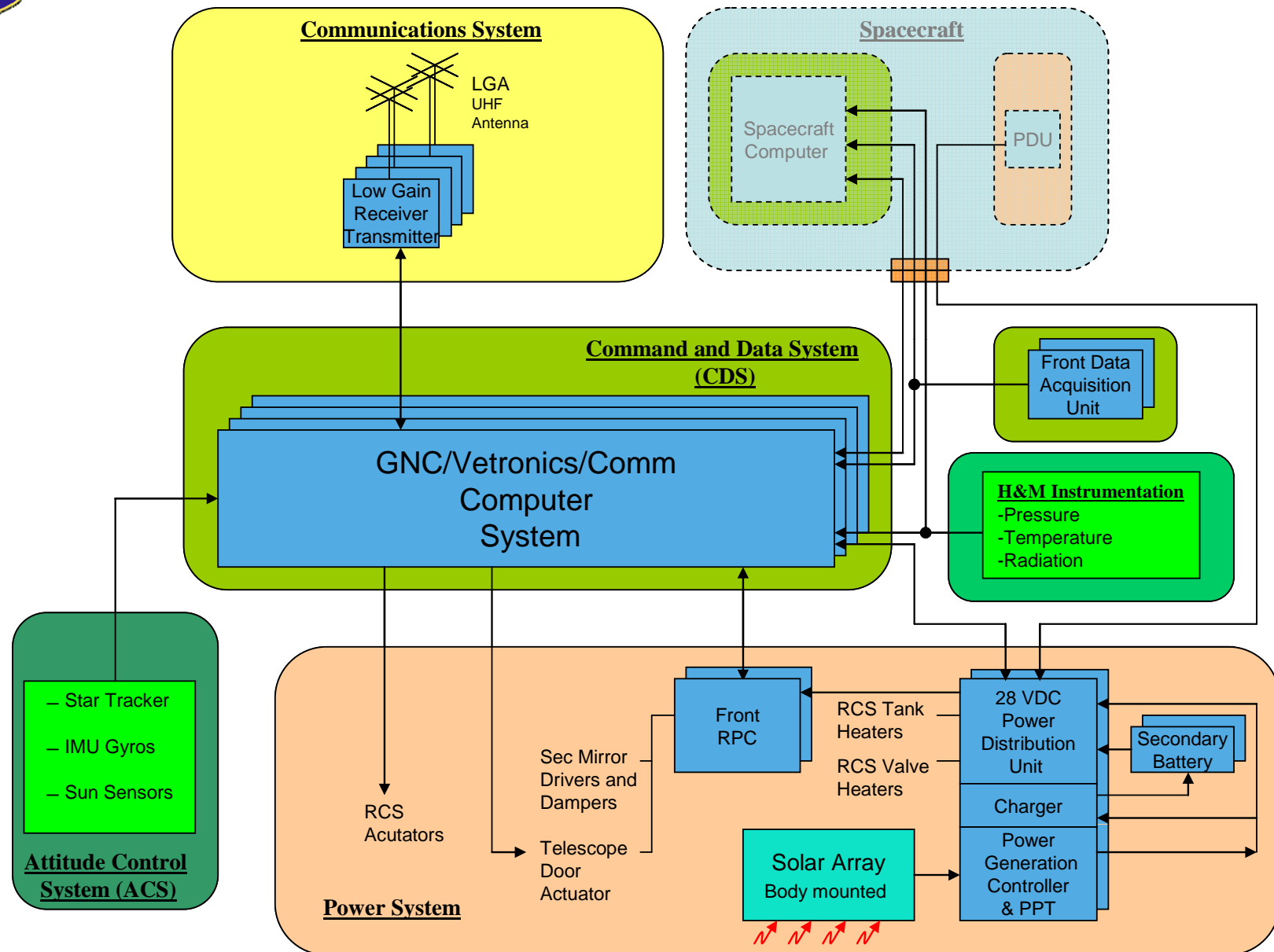
6m Telescope - Spacecraft Astrionics and Power Systems

3-7-07





Telescope Astrionics & Power Systems





Mission Life

Initial Mission designed for a 5 yr mission life (10 yr goal)
should produce compelling science results well worth the
modest mission cost.

But, there is no reason why the mission should end after 5 or
even 10 years.

Hubble has demonstrated the value of on-orbit servicing

The telescope itself could last 30 or even 50 years.



30 to 50 year Mission Life

Copy Ground Observatory Model – L2 Virtual Mountain

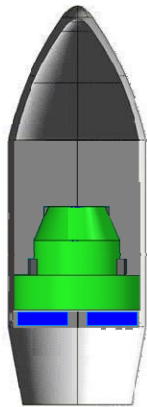
Design the observatory to be serviceable

Telescope has no inherent life limits

Replace Science Instruments every 3-5 yrs (or even 10 yrs)

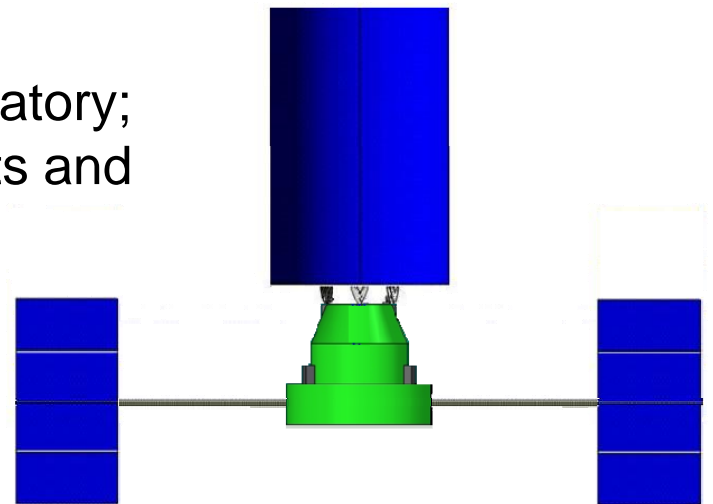
Replacement
Spacecraft in ELV

Observatory has split bus with on-board attitude control and propulsion during servicing. (already in mass budget)



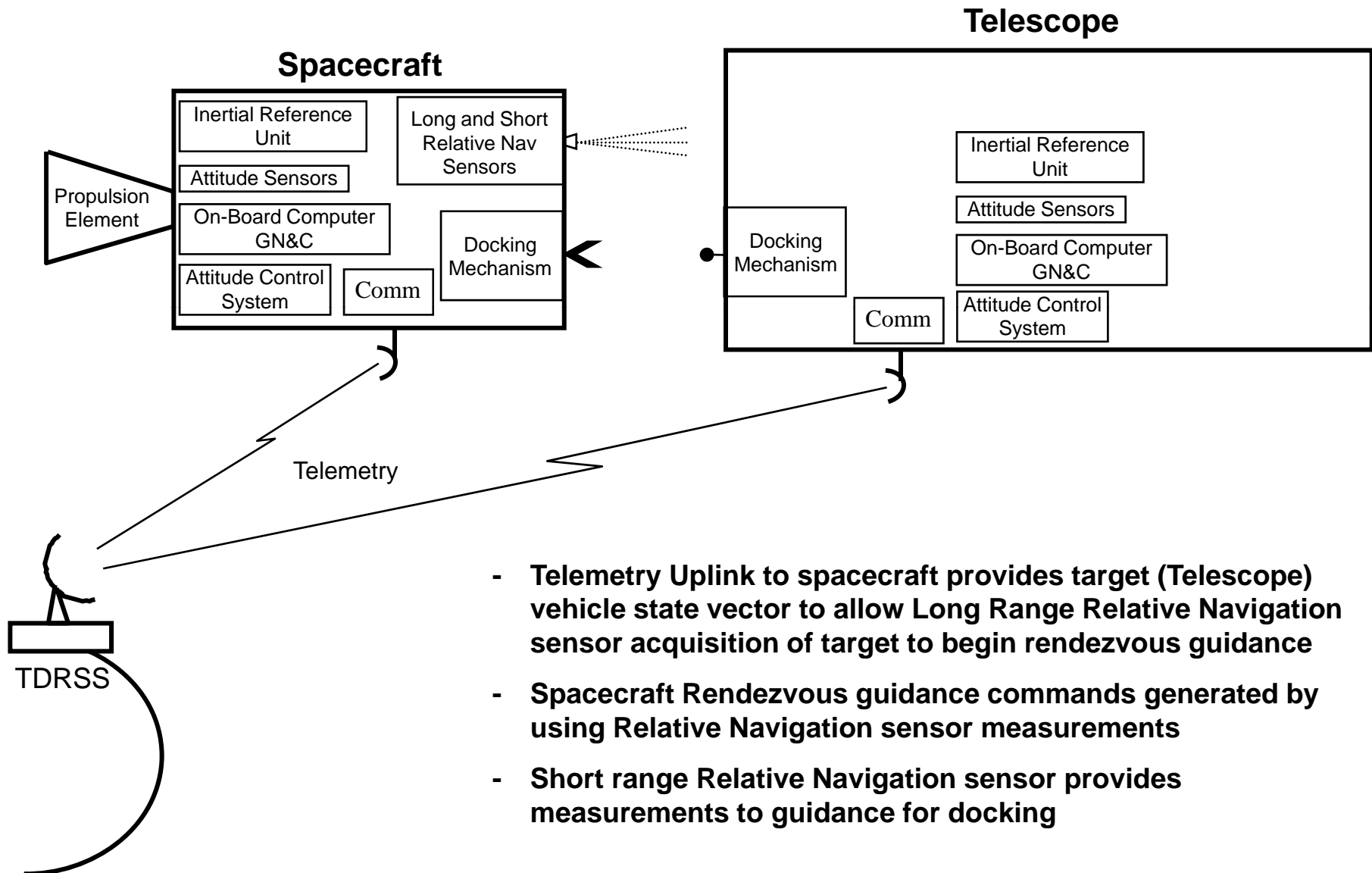
Spacecraft in
4.5 meter Payload Fairing

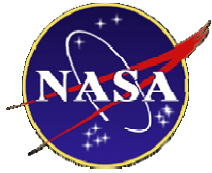
Autonomously docks to observatory;
replaces all science instruments and
ALL expendable components.





AR&D System Elements





Conclusions

The unprecedented mass/volume capability of an Ares V enables the launch of 8 meter class monolithic space telescopes to the Earth-Sun L2 point.

NASA MSFC has determined that a 6 to 8 meter class telescope using a massive high-TRL ground observatory class monolithic primary mirror is feasible.

Mature, High-TRL design enables early deployment.

Science Instruments, Expendables and Limited Life Components can be replaced periodically via Spacecraft Autonomous Rendezvous and Docking.



Any Question?

